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ELLIOT LAKE LABORATORY

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MAGNITUDE SCALING OF SEISMIC EVENTS AT ELLIOT LAKE

by

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ABSTRACT

As part of the Canada/Ontario/Industry rockburst project the seismograph stations of the Eastern Canada Seismic Network are being augmented by local seismograph stations at the mining camps experiencing rockbursts (Red Lake, Elliot Lake, Sudbury and Kirkland Lake). The primary reason for these local stations is to extend the range of seismic event magnitudes down to lower levels.

The seismograph station at Elliot Lake has been in operation for almost two years. During this time 31 seismic events at Quirke and Denison Mines have been recorded on the regional and local networks. Correlation between magnitude and amplitude of the seismic signal at Elliot Lake is poor. A much better relationship exists between magnitude (Mn) and time duration (t) of the seismic signal in the form:

$$M_n = 1.21 \log t + 0.27$$

This relationship is used to calculate magnitudes of seismic events 1.0 to 1.9 at Elliot Lake, while still relying on the regional network for magnitudes 2.0 and greater.

Key words: Seismicity; Monitoring; Magnitude; Elliot Lake.

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INTRODUCTION

Rockbursts first occurred at Rio Algom's Quirke Mine at Elliot Lake in March, 1982. These have continued, since that time, with varying levels of intensity. Also, the occasional rockburst has been recorded in the adjacent Denison Mine. A microseismic system was installed around the rockburst area at Quirke Mine in August 1982, primarily for source location. Subsequently, the system was expanded and some of the geophones were installed in the Denison Mine to provide coverage of the boundary pillar area.

Some of the larger seismic events* were recorded by the Eastern Canada Seismic Network, operated by the Geophysics Division of Energy, Mines and Resources Canada. The nearest seismograph stations to Elliot Lake are SUO in Sudbury (123 km) and EEO at Eldee (267 km). The estimated detection level for which the seismograph network can provide reliable information is a magnitude of 2.2 or greater, for the Elliot Lake mines (Hedley and Wetmiller, 1985). Accuracy of magnitude values is typically ± 0.3 units. With the installation of two additional seismograph stations (SWO and SZO) in the Sudbury Basin in May 1987, the detection level has been reduced to a magnitude of about 1.7.

To improve the range of seismic event magnitudes a Teledyne-Geotech short-period seismograph was installed at CANMET's Elliot Lake Laboratory in November, 1985. Since that time 31 seismic events of magnitudes 1.4 to 2.7 have been recorded by the Eastern Canada Seismic Network and the seismograph at Elliot Lake. This provides a reasonable data base to calibrate the Elliot Lake seismograph in terms of magnitude.

*The term 'rockburst' is reserved for a seismic event which causes damage to the mine workings.

MAGNITUDE SCALING

The magnitude values calculated by the Geophysics Division, for seismic events in Ontario, are based on the regional scale developed by Nuttli (1973) for eastern North America.

$$M_n = -0.1 + 1.66 \log (D) + \log (A/T) \quad \text{Eq 1}$$

where, M_n = magnitude

D = epicentral distance in km

A = maximum vertical zero-peak ground amplitude in micrometers

T = period of the ground motion at the peak value in seconds.

This scale is comparable to the original magnitude scale developed by Richter (1958) for California.

For the seismograph at Elliot Lake, the distances (D) to the Quirke and Denison Mines can be considered as constants. Since only a paper chart record is obtained, the period (T) cannot be measured and also must be taken as a constant. Consequently, magnitude (M_n) can only be compared to the maximum amplitude of the seismic signal. Figure 1 shows the typical seismic signals for a range of seismic event magnitudes. Since the station is only 12 km away from both mines the frequency of the signal is relatively high. Consequently, the stylus travels over the heat-sensitive paper at a rapid rate. This produces a weak trace and some difficulty in establishing the maximum amplitude.

An alternative measure of seismic event magnitude is the time duration of the seismic signal. A problem arises in determining the time at which the signal returns to background noise, as can be seen in Figure 1. To overcome this difficulty the time for which the signal was above ± 1 mm on the paper chart was measured.

The maximum amplitude of the P and S waves and the duration of the seismic signal for the thirty-one seismic events (29 at Quirke, 2 at Denison)

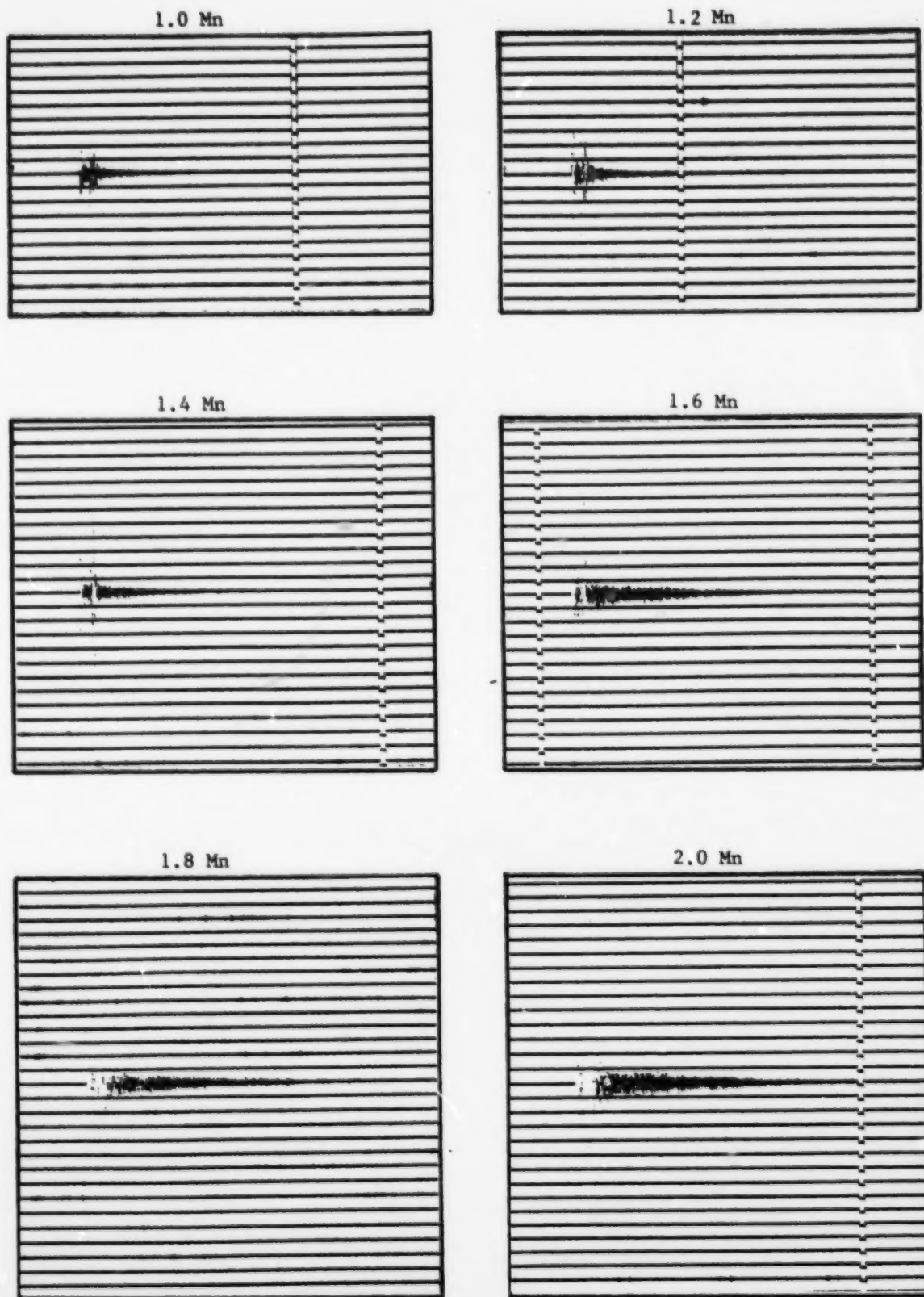


Fig. 1: Typical signals of seismic events 1.0 to 2.0 magnitude.

Table 1 - Seismic event parameters

Event No.	Date	Magnitude (Mn)	P peak (mm)	S peak (mm)	Duration (sec)
1	Jan. 1/86	1.9	21	22	14
2	Jan. 29/86	2.1	32	34	32
3	Jan. 31/86	1.4	15	16	17
4	Feb. 6/86	1.9	18	17	24
5	Mar. 9/86	1.9	23	20	13
6	Apr. 12/86	2.7	35	38	54
7	Apr. 13/86	1.9	30	25	24
8	Apr. 14/86	2.1	34	33	28
9	Apr. 17/86	1.9	30	34	23
10	Apr. 20/86	1.8	17	22	14
11	May 1/86	2.0	32	20	24
12	May 7/86	2.2	38	30	58
13	May 31/86	2.6	-	-	49
14	June 24/86	2.2	-	-	33
15	June 28/86	2.1	27	22	28
16	July 17/86	2.1	19	16	35
17	July 27/86	1.9	27	21	16
18	Aug. 1/86	1.9	32	36	28
19	Aug. 5/86	2.3	33	36	27
20	Oct. 17/86	2.5	40	38	50
21	Dec. 31/86	2.1	36	31	37
22	Dec. 31/86	2.2	37	36	45
23	Apr. 18/87	1.4	20	13	9
24	Apr. 19/87	1.6	18	23	15
25	May 31/87	2.1	37	36	49
26	June 14/87	1.7	24	28	19
27	June 25/87	2.0	29	29	36
28	June 27/87	1.8	29	34	29
29	Aug. 10/87	1.7	33	32	20
30	Aug. 28.87	2.3	37	35	37

are listed in Table 1. In 60% of the cases the amplitude of the P wave is greater than the S wave. This is unusual and the reasons for it are obscure. The amplitude of the S wave is used on the Eastern Canada Seismic Network stations; consequently, the S wave amplitude on the Elliot Lake seismograph is compared to magnitude values as illustrated in Figure 2. The correlation is poor. The anticipated relationship of log amplitude being proportional to magnitude is only indicated for magnitudes below 1.7. In 50% of the cases the maximum amplitude exceeds the linear response of the stylus, indicating saturation. Consequently, only the lower end of the magnitude scale of the Eastern Canada Seismic Network overlaps with the Elliot Lake seismograph.

Figure 3 shows the relationship between magnitude and duration of the seismic signal. This time there is a clear trend in the form:

$$M_n = 1.21 \log t + 0.27 \quad \text{Eq 2}$$

The scatter of the results fall within ± 0.3 magnitude units, which is within the accuracy of the magnitude values obtained from the regional network.

Using Equation 2, the time duration of magnitudes over 1.0 were calculated as listed in Table 2. From 1 January 1986 to 30 September 1987, 583 seismic events from the Quirke and Denison Mines were recorded on the Elliot Lake seismograph. Magnitudes were assigned to these events based on Equation 2, and 121, or 20%, had a magnitude of 1.0 or greater. The distribution of these larger seismic events by magnitude is shown in Figure 4. Those recorded by the Eastern Canada Seismic Network are also illustrated. Seismic events of magnitude 2.0 and greater were all recorded by the regional network. There is a partial overlap between magnitudes 1.4 and 1.9. Magnitudes of 1.3 or less are only recorded on the Elliot Lake seismograph.

Based on these results the Elliot Lake seismograph will be used to assign magnitudes of 1.0 to 1.9. For seismic events 2.0 and greater the regional network magnitude values will be used.

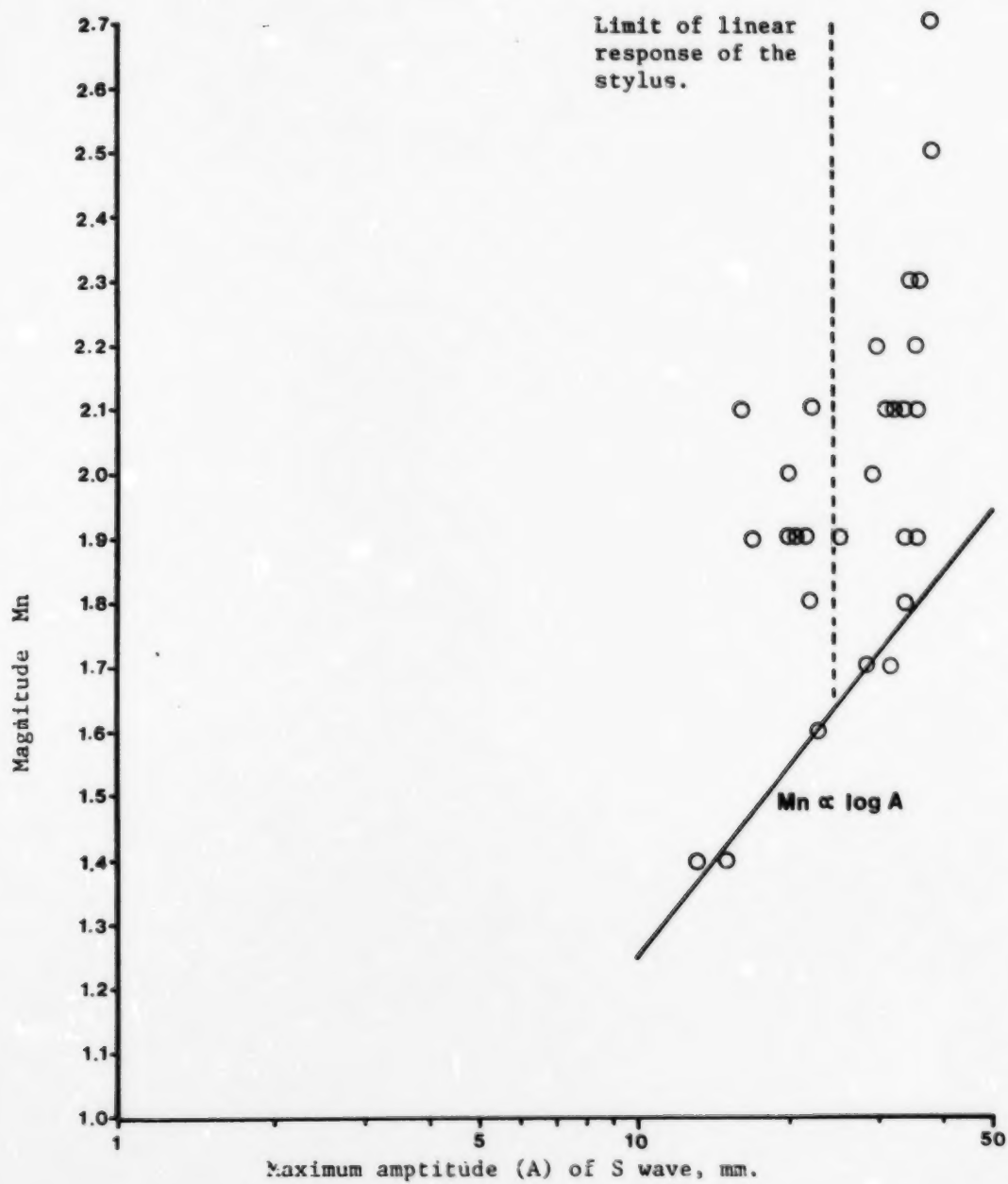


Fig 2: relationship between magnitude and amplitude of seismic events.

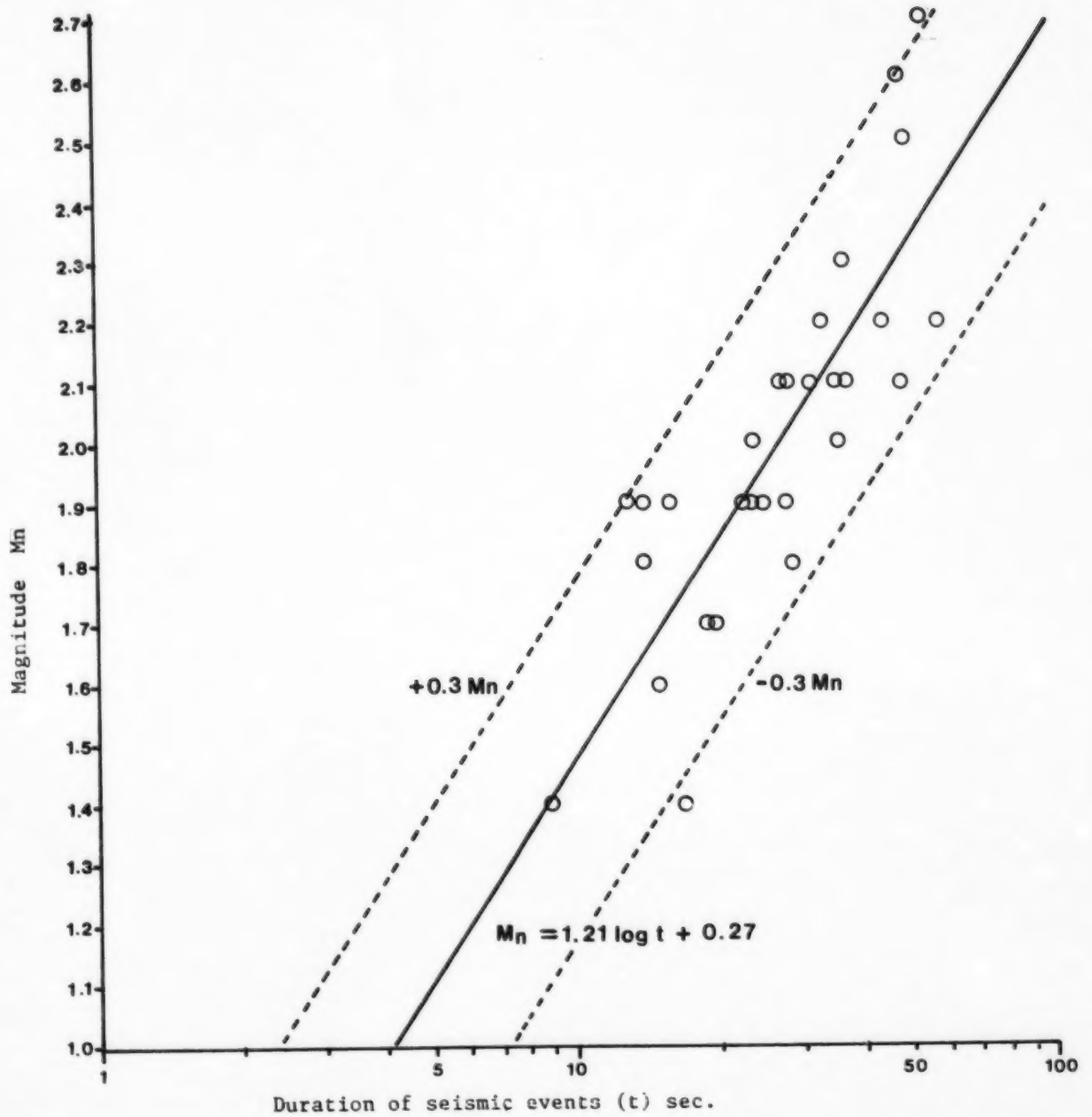


Fig 3: Relationship between magnitude and duration of seismic events.

Table 2 - Magnitude scale for Quirke and Denison Mines
based on duration of seismic signal above ± 1 mm.

Mn	Duration
<1.0	less than 3.6 sec
1.0	3.6 to 4.4 sec
1.1	4.4 to 5.3 sec
1.2	5.3 to 6.5 sec
1.3	6.5 to 7.8 sec
1.4	7.8 to 9.5 sec
1.5	9.5 to 11.5 sec
1.6	11.5 to 13.8 sec
1.7	13.8 to 16.8 sec
1.8	16.8 to 20 sec
1.9	20 to 25 sec
2.0	and over recorded by Eastern Canada Seismic Network

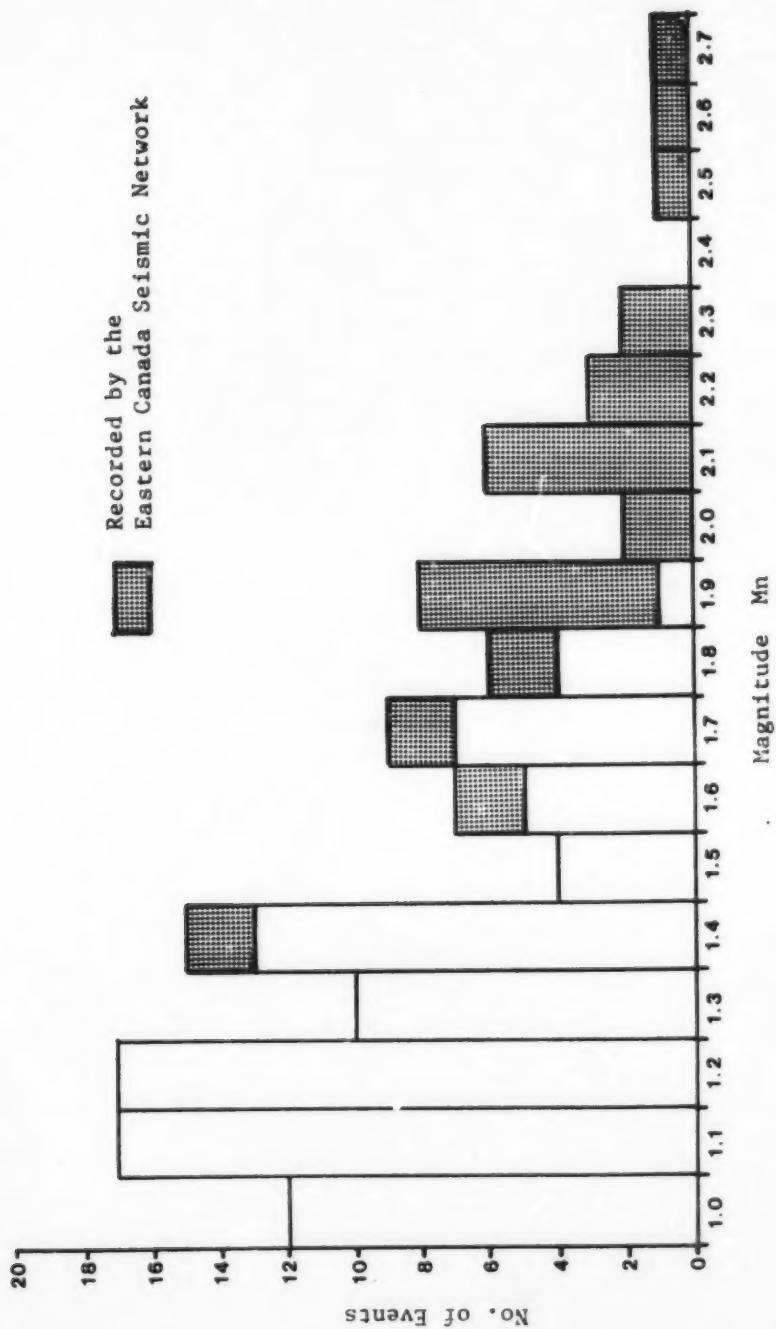


Fig 4: Distribution of seismic events by magnitude (Jan. 1986 to Sept. 1987)

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